Heat conduction engineering with phonon resonances

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Understanding the design rules to obtain materials that enable tight control of phonon transport over a broad range of frequencies would aid major developments in thermoelectric energy harvesting, heat management in microelectronics and information and communication technology. In this talk, we introduce a new heat conduction control techniques using surface phonon resonant structures in Si-based nanostructures and discuss the new possibility of heat conduction control by synergistic effect of resonances and scattering.

With atomistic simulations, we demonstrate that the surface resonant structures can introduce numerous flat bands across the entire Brillouin zone, which can hybridize with the propagating phonons due to the anti-crossing effect [Fig. 1(a,b)] [1]. The resonant flat bands can facilitate the momentum conservation of phonon scattering, thus increase the phonon phase space (scattering channels) and diminishes the relaxation time noticeably [Fig. 1(d)] [2]. While the hybridization effect can directly reduce the phonon group velocity in the entire frequency range [Fig. 1(c)]. The resonant frequency, hybridization strength can be tuned by the height and period of resonators, respectively. Moreover, we demonstrate that instead of using periodic resonators to provide regular flat bands, surface amorphous structures can provide random phonon resonances. The use of amorphous coatings can facilitate the experimental sample synthesis and broaden the application of resonant mechanism. One of the merit for the resonant mechanism is that it can shorten the low-frequency phonon mean free path by more than 2-orders of magnitude[1,3], which make it an ideal candidate to synergistically impede the entire frequency phonon transport with the scattering mechanism [Fig. 1(e)].

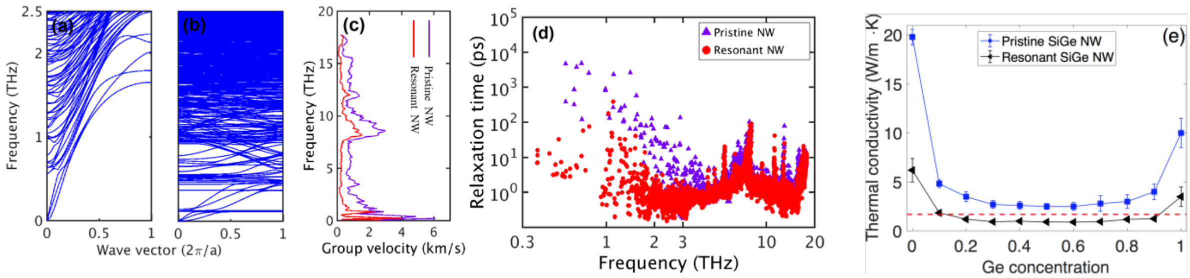

Figure 1. Phonon dispersion relation of pristine (a) and resonant (b) NWs; Phonon group velocities (c) and relaxation time (d) of pristine and resonant NWs; Thermal conductivity of pristine and resonant SiGe NWs.

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